Research for Climate Protection: Model Run Evaluation

Project Year 3

Reclip:more – BOKU-Met

Precipitation evaluation of 10 year RCM runs on a daily basis


by

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1 Introduction

The special precipitation analysis was performed on a daily, monthly, seasonal and yearly basis for the period 1981-1990. Several statistical parameters have been calculated and summarised in various tables but also probabilities of precipitation and intensities have been investigated. In order to compare grid-point by grid-point all models were converted to the FREI-grid (see BOKU-Met project report of the second year). In order to verify the models we used the observational datasets HISTALP for monthly data (Efthymiadis et al, 2006) and the ETHZ dataset for daily data (Frei et al, 1998). Figure 1 shows the two sub-regional classifications we used for the analyses.

Figure 1: Climatologic sub-regions: HISTALP (left) and VERA classification (right)

The left one is the HISTALP classification, the right a subjective classification based on the IMG-VERA regions. While HISTALP draws a sharp north-south dividing line along the main Alpine ridge which is probably more suitable to display the climatic north-south contrast in the Alpine region, VERA distinguishes 6 regions around the Alps and the inner Alpine region, which is advantageous for analyses of smaller-scale regional climate features and RCM’s ability to reproduce them.
The main focus of the special precipitation analysis was the evaluation of the ERA40 driven Regional Climate Model (RCM) precipitation. This allows a day by day and month by month comparison with the observational data. A second task was to investigate the changes in RCM precipitation, when the RCMs are forced by GCM-control data. This investigation can only be done in a climatological sense, while the quantification of the climate change signal - scenario minus control - is mainly done by the modelling groups and can be found in the referring reports (Beck, 2006 and Gobiet et al, 2007). Within this report only a small set of quantitative results is included in selected tables. All additional available results are listed in the annex and are downloadable from the project’s homepage.

2 Precipitation evaluation

2.1 Climatological evaluation on a seasonal base

To give an overview of the differences between the models and the observations concerning the precipitation climatology of 1981-1990 we present the relative bias of MM5 and ALADIN against the ETHZ observation data in figure 2. The upper panel shows the results for ALADIN driven by ERA40 (hindcast) and ECHAM5 (control run) while the lower panel shows the results of the respective MM5 runs. Shown is the average bias in the period 1981-1990. In general all models tend to be too wet in most parts. Blue colours indicate more than 25 percent of increased precipitation and red colours less than 25 percent of precipitation. The white regions indicate that the models biases are within +/-25 percent range compared with the observations. As already seen in earlier studies, ALADIN is far too wet - with even more than 150 percent in many parts - while MM5 driven by ERA40 performs rather well in reconstructing the observations. In general the models produce too much precipitation especially over the Alps.

Figure 2: Relative bias of the average precipitation for the period 1981-1990: Upper panel ALADIN, lower panel MM5; Left side forced with ERA40 and right side forced with ECHAM5
Tables 1 - 3 summarise some quantitative information of the ERA40 driven model runs on seasonal and annual time scale. All results have been compared to the HISTALP data set and the results are given for all four HISTALP regions (h1-h4) and for the entire evaluation domain (denoted with "ges"). The relative bias is given by \((\text{mean(model)} - \text{mean(observation)}) / \text{mean(observation)}\).

Table 1: Relative bias [%] of the 1981-1990 precipitation means of the ERA40 driven model runs

<table>
<thead>
<tr>
<th></th>
<th>ala_ges</th>
<th>ala_h1</th>
<th>ala_h2</th>
<th>ala_h3</th>
<th>ala_h4</th>
<th>mm5_ges</th>
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<tbody>
<tr>
<td>DJF</td>
<td>7</td>
<td>1</td>
<td>18</td>
<td>-2</td>
<td>0</td>
<td>16</td>
<td>14</td>
<td>23</td>
<td>-1</td>
<td>22</td>
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<tr>
<td>MAM</td>
<td>31</td>
<td>39</td>
<td>51</td>
<td>6</td>
<td>24</td>
<td>10</td>
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<td>12</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>JJA</td>
<td>33</td>
<td>31</td>
<td>58</td>
<td>3</td>
<td>28</td>
<td>-4</td>
<td>-8</td>
<td>-1</td>
<td>-6</td>
<td>-2</td>
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<td>22</td>
<td>-11</td>
<td>0</td>
<td>-11</td>
<td>-5</td>
<td>-4</td>
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<td>-11</td>
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<tr>
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<td>19</td>
<td>37</td>
<td>-1</td>
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<td>2</td>
<td>3</td>
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<td>-6</td>
<td>3</td>
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</table>

Table 2: Variance ratio \([\text{var(model)}/\text{var(histalp)}]\) of the 1981-1990 precipitation means of the ERA40 driven model runs

<table>
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<tr>
<th></th>
<th>ala_ges</th>
<th>ala_h1</th>
<th>ala_h2</th>
<th>ala_h3</th>
<th>ala_h4</th>
<th>mm5_ges</th>
<th>mm5_h1</th>
<th>mm5_h2</th>
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<tbody>
<tr>
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<td>1.26</td>
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<td>0.98</td>
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<td>2.02</td>
<td>2.04</td>
<td>1.41</td>
<td>1.71</td>
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<td>0.94</td>
<td>0.79</td>
<td>0.84</td>
<td>0.77</td>
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<tr>
<td>SON</td>
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<td>0.94</td>
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<td>1.12</td>
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<tr>
<td>YEAR</td>
<td>1.73</td>
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<td>2.82</td>
<td>0.97</td>
<td>1.32</td>
<td>0.99</td>
<td>1.46</td>
<td>1.61</td>
<td>0.67</td>
<td>0.80</td>
</tr>
</tbody>
</table>

Table 3: Correlation \([\text{corr(model,histalp)}]\) of the 1981-1990 precipitation means of the ERA40 driven model runs

<table>
<thead>
<tr>
<th></th>
<th>ala_ges</th>
<th>ala_h1</th>
<th>ala_h2</th>
<th>ala_h3</th>
<th>ala_h4</th>
<th>mm5_ges</th>
<th>mm5_h1</th>
<th>mm5_h2</th>
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<td>0.85</td>
<td>0.72</td>
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<td>0.86</td>
<td>0.77</td>
<td>0.79</td>
<td>0.79</td>
</tr>
<tr>
<td>JJA</td>
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<td>0.82</td>
<td>0.64</td>
<td>0.79</td>
<td>0.77</td>
<td>0.78</td>
<td>0.76</td>
<td>0.76</td>
<td>0.77</td>
<td>0.81</td>
</tr>
<tr>
<td>SON</td>
<td>0.70</td>
<td>0.82</td>
<td>0.71</td>
<td>0.67</td>
<td>0.74</td>
<td>0.66</td>
<td>0.63</td>
<td>0.63</td>
<td>0.71</td>
<td>0.64</td>
</tr>
<tr>
<td>YEAR</td>
<td>0.71</td>
<td>0.84</td>
<td>0.64</td>
<td>0.70</td>
<td>0.75</td>
<td>0.71</td>
<td>0.79</td>
<td>0.67</td>
<td>0.72</td>
<td>0.71</td>
</tr>
</tbody>
</table>

Further investigations concerning statistical parameters like the mean, median, minimum, maximum and percentiles (5, 25, 75, and 95), correlation, efficiency and rms are summarised in a number of tables being too comprehensive to show here. The evaluations were performed for all analysis regions and for the entire year and all seasons as well as on daily and monthly basis. A list of these downloadable results can be seen in the annex of this report.

Figure 3 shows the “probability density function” (pdf) of the average precipitation for all seasons for the period 1981-1990. The black curve is the distribution of the HISTALP data. The Figures indicate that the models tend to have higher frequencies from 400 mm on than the observations, but in general the shape of the pdfs is similar. In spring (MAM) the peak near 180 mm is reproduced by MM5, which is generally in very good agreement with the observations. In summer the ALADIN models show even more pronounced high probabilities of reproducing the pdf of the HISTALP data. In autumn (SON) the ERA40 driven ALADIN run performs quite well, while the MM5_E40 model has too many events up to 100 mm and then too little values. For the other models it is just the other way...
2.2 Analysis of daily precipitation

The analysis of the daily precipitation gives some information about the reliability of the RCMs concerning precipitation extremes. An example for results concerning strong precipitation is shown in figure 3. In order to produce these pictures the probability $P$ of $RR>5\text{mm}$ was calculated for each grid-point for the time period 1981-1990 on a daily basis. The distribution of these values is summarised in figure 4.

The upper panel shows the results of the ALADIN run driven by ERA40 and ECHAM5, the mid panel shows the respective MM5 model runs on domain 2, while the observations of ETHZ are given at the end. We see that the probabilities range from 8% up to 32% with a clear peak at 15% in the observations. The $P(RR>5)$ value in the figures shows the overall value for the probability of $RR>5\text{mm}$. The observations have an overall probability of 16%. All models have higher values whereas the MM5 model driven by ERA40 is closest with 17%. Further all models have values exceeding the 32% maximum of the observation reaching up to 40% and even more by the ALADIN models. On the other hand the minimum value is reproduced more or less by all models.
The distributions shown in figure 4 were also fitted by a Gamma distribution in order to plot more than one distribution together and to compare different seasonal characteristics. Each panel in figure 5 shows the distributions of ALADIN_E40, ALADIN_EH5, MM5_E40_D2, MM5_EH5_D2 and of the ETHZ observational data for one season.

The seasonal differences can be seen best between summer (JJA) and autumn (SON). During summer the convective processes broadens the distribution, thus a lot of grid boxes have more than 20 percent of precipitation days with more than 5 mm precipitation. In autumn the distribution is quite small, centred at 15 %. These seasonal differences are reproduced quite well by both models, although both models - and especially ALADIN - overestimate the fraction of grid boxes with high percentages.
Figure 5: Fitted gamma distribution for the seasonal probability of daily precipitation higher than 5mm (whole analyses domain)

Figure 6 pictures the distribution of the mean seasonal precipitation intensities (precipitation sum per number of days with precipitation). Here histograms have been calculated and the values of the classes have been interpolated by splines giving curves that enfold the distribution. The left column summarises the results for the north east VERA region 3, while the right column shows results for region 6 (Po basin). The rows show the seasons from spring to winter. Here various comparisons can be made. The regional differences can be quantified by comparing the left and the right column.

Region 3 has a narrow peak while the distribution of region 6 is more spread reaching higher values. Low intensities origin in general from more stratiform precipitation while higher values are more linked to convective processes. This indicates that region 6 is dominated by convective processes rather than region 3. Comparing row by row gives the different distributions of the seasons. If we concentrate on the observations (black curve) we see that in region 3 spring (MAM) and autumn (SON) are similar showing one single peak at about 3.75 mm/day. Winter (DJF) and summer (JJA) have a wider range of intensities and the peaks are at 2.5 and 4.25 mm/day respectively. Region 6 has more or less similar distributions over the entire year having the peak at about 5mm/day.

The quality of reproduction of these distributions by the models is different in each season. In general the distributions of the models seem to be all shifted towards lower values and the maximum frequency of the models seems to be higher except in spring (MAM) in region 3. The most difficulties occur in region 6 in JJA where the distributions of the models show maximum frequencies around 2 – 3 mm where the observations are still quite low. The high frequency of very low intensities is also caused by the factor, that RCM produce a lot of days with very low precipitation. For the analyses all daily precipitation sums below 0.05 mm where set to zero, but still a lot of days with little precipitation are found. To get a realistic pdf from the models a threshold of 0.3 mm is necessary.
In order to get an idea how good extreme events have been modelled, the distribution of the 98 percentile of three-day-precipitation sums of was examined. These results are shown in figure 7. Here we see that from 70 mm on all models except ERA40 driven MM5 have higher frequencies. This means that there is a certain shift of the precipitation towards stronger events.
2.3 Reanalyses versus GCM-control forcing

The shift from ERA40 to GCM forcing modifies both RCM precipitations results in a similar way. For the entire analysis region and year the precipitation increases by ~15% in ALADIN and 24% in MM5 (compare figure 2). This increase can also be seen in figure 3, where a decrease of numbers of grid points with low precipitation and an increase of high precipitation grid points can be seen. This is especially pronounced in autumn and winter in both models. During spring roughly no changes can be seen and in summer both RCMs react different. MM5 shows no significant change while ALADIN shows a clear decrease in precipitation by ~15%. This different behaviour in summer explains the differences of both models in reaction to the change in forcing. Physical causes for these differences are not clarified till now, but may be connected to the convection.

The shift of forcing does not effect the spatial correlation. This shows that the main factors for the spatial precipitation distribution are the mountains, and no massive differences in flow directions exist between ERA40 and ECHAM5 forcing. The spatial variability strongly increases with GCM forcing in both models and especially in the winter season.

Concerning daily precipitation statistics, GCM forcing leads also to an increase of strong precipitation events. In figure 7 the increase in 3 day-precipitation-sums above 100 mm strongly increases for ALADIN as well as for MM5. Similar results can be seen for the precipitation intensities in figure 6, with the exception of ALADIN in summer and especially in the Po basin. This might indicate that the differences between the models in summer may stem from handling of the convective processes, as the Po basin precipitation in summer mainly stems from convection.

3 Conclusions

The spatial representation of the average precipitation within the Alpine regions is reproduced very realistically by both RCMs. The correlation coefficient for the seasonal precipitation sums ranges between 0.6 and 0.9 depending on region and season. As shown in figure 2, the ERA40 driven ALADIN model (upper left panel) overestimates the precipitation within the mountains. The picture within the mountains is very patchy, even single hills or ranges can be detected. The reason seems to be an overestimation of the water flux convergence on this hills and ranges. Additionally this over-
estimation of the precipitation might be caused by the used “downscaling approach”. As ALADIN is re-initialized every day, the detrainment caused by the orography is not seen by the initial fields, which leads to higher water content in the initial fields (personal communication with Michel Deque).

MM5 (lower left panel in figure 2) shows much smoother biases. The precipitation is underestimated in the northern and southern “Stau”-regions and overestimated along the Alpine main ridge.

ALADIN is generally much wetter than MM5 and the observations and overestimates the 10 year precipitation in the entire analysis domain by 19%, while MM5 overestimates by only 2%. But it must be stated here, that HISTALP and ETHZ precipitation data are rather low estimates of the real Alpine precipitation, due to the problems of precipitation measurements at high elevations. ALADIN is much too wet in spring and summer and fits quite good in autumn and winter. MM5 overestimates the precipitation in winter and spring, fits quite well in summer and underestimate in autumn.

For the distribution of the grid point precipitation (see figure 3) the MM5 results are much closer to the observation than the ALADIN results. The ALADIN distribution is much broader, as on many grid points within the Alps the precipitation is overestimated. The general wetter conditions in ALADIN lead also to an overestimation of days with precipitation above 5 mm (figure 4 and 5), but existence of a lot of grid points with more than 5 mm precipitation per day on more than 40 % of all days can only be explained by an overestimation of the orographic precipitation on this grid points.

The change from ERA40 forcing to ECHAM5 forcing introduces an additional increase of RCM precipitation. Interesting for further investigations is the different behaviour of the RCMs to the shift of forcing in summer. MM5 show no change in precipitation and in ALADIN the precipitation decreases, which leads to smaller changes in the yearly sum.

Both models show a typical, but different behaviour forced by ERA40 as well as by changing the forcing to ECHAM5. This might also introduce some differences in the climate change signal. A ranking of the models concerning precipitation reproduction is not possible. They can be interpreted as two independent regional realisations for the same large scale forcing.

4 References


Annex - list of additional result files on http://systemsresearch.arcs.ac.at/projects/climate/

File: bias_eh5.pdf
monthly bias, ratio of variances and correlation for the period means of the ECHAM5 driven models

File: corr_eff.pdf
daily correlation and efficiencies for the entire period 1981-1990 and for seasons

File: kenn_s.ps
Seasonal statistical parameters for all models on a monthly basis and for all regions

parameter
mean of DJF - total domain
median, std, maximum, minimum, rms, eff, corr for DJF - total domain
rr sum DJF - total domain DJF
mean, std, max, min, rms, eff, corr DJF for HISTALP regions
mean, std, max, min, rms, eff, corr DJF for VERA regions
mean of MAM - total domain
median, std, maximum, minimum, rms, eff, corr for MAM - total domain
rr sum MAM - total domain
mean, std, max, min, rms, eff, corr MAM for HISTALP regions
mean, std, max, min, rms, eff, corr MAM for VERA regions
mean of JJA - total domain
median, std, maximum, minimum, rms, eff, corr for JJA - total domain
rr sum JJA - total domain
mean, std, max, min, rms, eff, corr JJA for HISTALP regions
mean, std, max, min, rms, eff, corr JJA for VERA regions
mean of SON - total domain
median, std, maximum, minimum, rms, eff, corr for SON - total domain
rr sum SON - total domain
mean, std, max, min, rms, eff, corr SON for HISTALP regions
mean, std, max, min, rms, eff, corr SON for VERA regions

11
File: kennz_m.ps

Monthly statistical parameters for all models and for all regions

parameter
page

mean annual rr sums
1
mean,median,std,max,min,rms,eff,corr of the period 1981-1990
1
annual rr sums
1
mean,median,std,max,min,rms,eff,corr of the single years for 1981-1990
1
mean for entire period 1981-1990 for all HISTALP regions
2
mean for each single year for all HISTALP regions
2
median for each single year for all HISTALP regions
4
std for each single year for all HISTALP regions
5
max for each single year for all HISTALP regions
6
min for each single year for all HISTALP regions
7
rms for each single year for all HISTALP regions
8
eff for each single year for all HISTALP regions
9
corr for each single year for all HISTALP regions
10
mean for entire period 1981-1990 for all VERA regions
11
mean for each single year for all VERA regions
12
median for each single year for all VERA regions
13
std for each single year for all VERA regions
14
max for each single year for all VERA regions
15
min for each single year for all VERA regions
16
rms for each single year for all VERA regions
18
eff for each single year for all VERA regions
19
corr for each single year for all VERA regions
20

File: kennz_reg_y.ps

statistical parameters for all models on a daily basis for the entire period of 1981-1990

parameter
page

Mean, median, min, max and percentiles (5,25,75,95) for HISTALP regions
1
Mean, median, min, max and percentiles (5,25,75,95) for VERA regions
1
statistical seasonal parameters for all models of daily data

Mean, median, min, max and percentiles (5,25,75,95) for the entire HISTALP region (H0) for season DJF

Mean, median, min, max and percentiles (5,25,75,95) for region H1 for all seasons

Mean, median, min, max and percentiles (5,25,75,95) for region H2 for all seasons

Mean, median, min, max and percentiles (5,25,75,95) for region H3 for all seasons

Mean, median, min, max and percentiles (5,25,75,95) for region H4 for all seasons

Mean, median, min, max and percentiles (5,25,75,95) for the entire VERA region V0 for season DJF

Mean, median, min, max and percentiles (5,25,75,95) for region V1 for all seasons

Mean, median, min, max and percentiles (5,25,75,95) for region V2 for all seasons

Mean, median, min, max and percentiles (5,25,75,95) for region V3 for all seasons

Mean, median, min, max and percentiles (5,25,75,95) for region V4 for all seasons

Mean, median, min, max and percentiles (5,25,75,95) for region V5 for all seasons

Mean, median, min, max and percentiles (5,25,75,95) for region V6 for all seasons

Mean, median, min, max and percentiles (5,25,75,95) for region V7 for all seasons